Nichols

Compliments of Wm. Ripley Nichols.

[*From the Annual Report of the Water Commissioners, 1878.*]

REPORT

—OF—

Professor Nichols

—TO THE—

Water Commissioners, Springfield, Mass.

C. O. Chapin, Esq., *President of the Water Commissioners of the City of Springfield.*

Dear Sir:—I have during a considerable portion of the present year made weekly examinations of water collected at the Gate House in the Ludlow Reservoir, by Mr. A. L. Graves, in charge of the Reservoir. The results of these examinations are indicated in the accompanying Tables.

During the month of January and a portion of February the water was very clear and free from color; since that time there has usually been a greater or less amount of turbidity, and the water has generally possessed a slight color. The suspended matter is in the main of vegetable origin, and for a considerable part of the year is due to the growth of minute vegetable organisms in the reservoir, as has been noticed and described in previous reports of your Board. At the beginning of April the water contained a great number of the hibernating eggs of a species of *Daphnia*, which in the warm laboratory hatched out so that the water was filled with these animalculæ. These were more abundant than any other form of animal life, and most abundant during the month of April. Rather early in May the vegetable organisms already alluded to began to appear and continued, with interruptions, through the Summer. I may mention that in addition to the *clathrocystis aeruginosa*, which occurs so abundantly every year, there is also a very considerable quantity, at times at least, of another plant, also one of the *algæ*, the *anabæna circinalis*. This latter plant, however, is much more readily broken up than the *clathrocystis*, and I have discovered only traces of it in the water when received for analysis. I found an abundance in the reservoir on the 5th of July, and no doubt it would be readily found at almost any time during the Summer.

Table I.—Examination of Water from Ludlow Reservoir.

[Results expressed in Parts in 100,000.]

Date Received.	Unfiltered Water.		Filtered Water.*		Dissolved Matter.			Suspended matter.**	Height of water in Reservoir.
	Ammonia.	"Albuminoid Ammonia."	Ammonia.	"Albuminoid Ammonia."	Inorganic.	"Organic and Volatile."	Total at 212° Fah.		
January 3, 1877,	0.0168	0.0368	0.0168	0.0363	1.92	3.00	4.92	0.36	11.08
" 9, "	0.0293	0.0291	0.0293	0.0283	1.36	2.56	3.92	0	11.00
" 17, "	0.0261	0.0352	0.0261	0.0347	2.48	3.20	5.68	0	10.95
" 24, "	0.0237	0.0277	0.0237	0.0267	2.08	3.44	5.52	0	10.81
" 30, "	0.0229	0.0285	0.0229	0.0283	2.00	3.44	5.44	0	10.66
February 14, "	0.0187	0.0320	0 0187	0.0309	2.16	3.40	5.56	0.48	
" 21, "	0.0104	0.0317	0.0104	0.0307	3.00	3.72	6.72	0.96	
" 27, "	0.0045	0.0376	0.0045	0.0288	2.80	3.20	6.00	0.24	10.86
March 6, "	0.0024	0.0309	0.0024	0.0299	1.96	2.80	4.76	0.36	11.82
" 14, "	0.0027	0.0304	0.0027	0.0299	2.44	3.12	5.56	0.32	13.80
" 20, "									14.61
" 27, "	0.0056	0.0341	0.0056	0.0197	1.64	2.20	3.84	0.76	16.28
April 4, "	0.0048	0.0277	0.0048	0.0203	1.48	1.88	3.36	1.08	18.98
" 10, "	0.0056	0.0237	0.0056	0.0195	1.64	2.76	4.40	0.56	19.93
" 24, "	0.0155	0.0173	0.0155	0.0160	1.76	2.28	4.04	0	21.00
May 1, "	0.0149	0.0189	0.0149	0.0179	1.80	2.28	4.08	0	21.21
" 9, "	0.0179	0.0232	0.0179	0.0192	1.68	2.28	3.96	0.40	21.29
" 15, "	0.0083	0.0269	0.0083	0.0256	1.96	2.00	3.96	0.28	21.46
" 22, "	0.0053	0.0261	0.0053	0.0216	1.60	2.76	4.36	0	21.42
" 29, "	0.0109	0.0275	0.0109	0.0269	1.84	2.60	4.44	0.72	21.32

June 6, ...	0.0099	0.0336	0.0091	0.0312	1.64	2.84	4.48	1.92	21.10
" 13, ...	0.0077	0.0352	0.0075	0.0339	1.80	2.12	3.92	0.60	
" 20, ...	0.0077	0.0288	0.0077	0.0275	1.92	1.92	3.84	0.24	21.21
" 27, ...	0.0075	0.0899	0.0075	0.0363	1.88	3.48	5.36	1.24	21.01
July 5, ...	0.0056	0.0637	0.0056	0.0320	1.52	3.48	5.00	0.92	21.00
" 11, ...	0.0205	0.0397	0.0205	0.0269	2.00	2.64	4.64	0.92	20.94
" 18, ...	0.0099	0.0936	0.0099	0.0371	1.40	2.88	4.28	3.04	21.18
" 25, ...	0.0061	0.0395	0.0061	0.0269	1.64	2.64	4.28	1.32	21.24
August 1, ...	0.0208	0.0331	0.0208	0.0269	2.08	2.04	4.12	0.76	21.15
" 7, ...	0.0195	0.0331	0.0195	0.0285	2.24	2.60	4.84	0.76	20.97
" 14, ...	0.0403	0.0357	0.0403	0.0323	3.72	2.52	6.24	0.76	20.78
" 21, ...									20.94
" 29, ...	0.0141	0.0477							20.55
September 5, ...	0.0059	0.0397	0.0059	0.0269	2.84	2.08	4.92	0.44	20.36
" 19, ...	0.0104	0.0363	0.0104	0.0261	2.68	2.36	5.04	1.00	19.84
" 25, ...	0.0080	0.0533	0.0080	0.0336	3.44	2.04	5.48	0.68	19.66
October 2, ...	0.0088	0.0547	0.0088	0.0224	3.76	2.04	5.80	1.32	19.46
" 10, ...	0.0160	0.0629	0.0160	0.0432	3.16	2.00	5.16	0.76	19.67
" 16, ...	0.0131	0.0472	0.0131	0.0371					
" 23, ...	0.0181	0.0458	0.0181	0.0373					19.75

* Filtered through paper.

** In the Tables the "Suspended Matter" is not the result of direct determination, but is the difference between the solid residue of the water as received and of the water after filtration through paper. It can therefore be regarded only as an approximate statement.

Table II. — Examination of Water from Ludlow Reservoir,—Monthly Averages.

[Results expressed in parts in 100,000.]

MONTH.	No. of samples.	Unfiltered Water.		Filtered Water. **		Dissolved Matter.			Suspended Matter **	Height of water in Reservoir.
		Ammonia.	"Albuminoid Ammonia."	Ammonia.	"Albuminoid Ammonia."	Inorganic.	"Organic and Volatile"	Total at 212° Fah.		
1876.*										
July,	8	0.0212	0.0472	0.0212	0.0336	2.21	2.72	4.93	0.52	21.32
August,	10	0.0120	0.0554	0.0120	0.0295	2.19	2.84	5.03	1.56	20.70
September,	8	0.0390	0.0748	0.0390	0.0344	2.37	2.93	5.20	1.65	19.41
October,	9	0.0070	0.0470	0.0070	0.0296	1.88	2.80	4.68	1.09	17.18
November,	6	0.0064	0.0367	0.0064	0.0320	1.80	2.92	4.72	1.75	13.43
December,	4	0.0121	0.0372	0.0121	0.0354	2.02	3.08	5.10	0.57	11.38
1877.										
January,	5	0.0238	0.0315	0.0238	0.0309	1.97	3.13	5.10	0	10.90
February,	3	0.0112	0.0338	0.0112	0.0301	2.65	3.44	6.09	0.56	11.86
March,	3	0.0035	0.0318	0.0035	0.0265	2.01	2.71	4.72	0.48	14.13
April,	3	0.0086	0.0229	0.0086	0.0185	1.62	2.31	3.93	0.55	19.97
May,	5	0.0115	0.0245	0.0115	0.0222	1.78	2.38	4.16	0.28	21.34
June,	4	0.0082	0.0469	0.0082	0.0322	1.81	2.59	4.40	1.00	21.11
July,	4	0.0105	0.0591	0.0105	0.0307	1.64	2.91	4.55	1.55	21.09
August,	3	0.0247	0.0474	0.0247	0.0292	2.68	2.39	5.07	0.76	20.88
September,	3	0.0081	0.0431	0.0081	0.0289	2.99	2.16	5.15	0.70	19.96

* The results of the examinations made in 1876 were published in the last Annual Report.

** See Notes to Table I.

Although there has been, as I understand, little complaint from the consumers during the present year, the water has occasionally possessed a noticeable green color and a rather marked vegetable taste, owing to the entrance into the pipes,.in a more or less decayed state, of the minute *algæ* which have abounded in the pond.

Although this vegetable growth is due to natural causes and, as far as we know, has no direct influence on the wholesomeness of the water, the question arises whether it would be practicable by any means to avoid the liability of even occasional annoyance.

It has been suggested that the extension of the pipe further out into the pond would be of value, as thus it would be possible to avoid much of the material which collects as a scum on the surface and is driven to the shore. As, however, the scum is readily broken up and the vegetable organisms scattered through the water even to a considerable depth, this would not afford constant relief. It has also been suggested that the water might be filtered before being delivered to the consumers. The filtration of the entire supply of a great city is by no means impracticable, and the water supply of London and of other cities in Great Britain and on the Continent has been thus filtered for many years. Filtration, with special regard to the conditions of our own State, is the subject of an article which will appear in the Report of the State Board of Health for 1878, and to that reference can be made for fuller details; I may, however, here give an account of some experiments made in filtering the Springfield (Ludlow) water and state the conclusions arrived at, and the conditions under which filtration on the large scale might be expected to give satisfactory results.

Up to the present time no filtering material has proved practically available on the large scale, except sand, although various attempts have been made to use other substances. There are as yet very few cities in this country which attempt to filter their water; the only two* in this region of which I have any personal knowledge, being Poughkeepsie and Hudson on the Hudson River

* I except the considerable number of towns and cities supplied with water collected in basins or galleries alongside of lakes or rivers. Although this method is spoken of as "natural filtration," it is something entirely distinct from the method now under discussion. See Report of State Board of Health before alluded to.

in the State of New York. In Europe, however, filtration is very commonly practiced.

Filter-beds, as usually constructed, are water-tight basins some 10 feet deep, the sides built of solid masonry and the bottom puddled or paved with brick and cemented. The area may be from 20,000 to 50,000, or in some cases even 150,000 square feet. In building up the filtering-bed, provision is first made for the ready collection of the water by laying upon the floor of the basin drains or channel-ways of stone or brick laid dry; then follows a layer of broken stone, the fragments being 3 or 4 inches in diameter. This is succeeded by gravel screened so as to be of uniform size, a layer of coarse being followed by one or more layers of finer material; upon the gravel rests sand likewise separated into layers of uniform size. The exact thickness of the different layers and the extent to which the separation into the different sizes is carried are subject to variation.

The operation of cleaning the filters consists in removing the sand to a slight depth, not over an inch, washing it and returning it to the beds. The frequency with which the beds require cleaning depends upon the condition of the water, and varies from once a week to once in six or eight weeks.

I should not attempt to estimate with any degree of accuracy the cost of laying out such filter-beds as would be necessary if the water of the Ludlow Reservoir were to be filtered; this would be a question for a professional engineer. We may, however, form some idea of the expense from what is known of the cost of other works. The original cost of the Poughkeepsie filtering works is stated to have been about $55,000. These beds have a total area of nearly 30,000 square feet, which at the usually accepted maximum rate of 90 gallons per square foot per day would give a capacity for 2,700,000 gallons per day, if all the sand area could be used at the same time. To filter 5,000,000 gallons of Ludlow water daily (this is the amount which the present pipes can supply) would require an area of 82,500 square feet, best perhaps in three beds, each of 27,000 square feet area, two of which could always be in operation while the other one was in process of cleansing. The cleaning of the filter-beds in Summer might be necessary as often as once a week, as the vegetable matter, which is most desirable to remove, clogs the filters rapidly. To keep the works in order would require the constant

attendance of some one intelligent person, and in cleaning the beds a number of laborers would be employed as often as should be found necessary. The cost of maintenance, including cleaning the beds, attendance and repairs, is more difficult to estimate than the cost of construction. It would seem from Mr. Kirkwood's work on the Filtration of River Waters, that at the English works the cost is from one to two dollars per 100,000 gallons. At Poughkeepsie, the cost of maintenance (including sand purchased) in 1876 was $3.50 per million gallons filtered; in 1877, about $2.55. At Hudson it is supposed to be very much less, but no accurate account is kept. In filtering the large amount which would be required for Springfield the expense would probably be less than at Poughkeepsie, and it would seem that it ought not to cost more than $2.50 per million gallons.

I should not recommend any city or town in our climate to construct filter-beds unless they were to be covered over, because the exposure to a hot Summer's sun of a comparatively thin layer of water is likely to cause the rapid growth and development of minute vegetable organisms, which not only clog the filter but tend by their decay to injure the taste of the water. In Winter, also, the covering would protect the beds to a certain extent, although it would be impracticable to prevent ice from forming. I regard it further as essential that water of this character, if filtered, should not be stored thereafter in open reservoirs, or be mixed with other water which has been so stored, but should be delivered at once into the service-mains, or if stored should be stored only in small covered reservoirs which could be readily emptied and cleaned if necessary.

I should not anticipate any trouble in distributing the filtered water through the present mains, although at first the effect of filtration might be in part neutralized by the deposit in the pipes; but after a short time, with proper flushing, this difficulty would pass away.

It will thus appear that to filter the Ludlow water a considerable outlay would be necessary. The question next to be considered is, "How much would be gained in the quality of the water by such filtration?"

Although the experience in other places has shown that it is possible by sand filtration to remove a small proportion of substances which are actually dissolved in the water, still this action

is comparatively insignificant, and for practical purposes may be left out of the question. A properly constructed and properly maintained sand filter would remove from a water like the Ludlow water everything that is in suspension, and in a Summer like the past one this would be all that would be necessary. If, however, as was the case two years ago, the vegetable matter accumulating on the shores of the pond should under exposure to the hot rays of a Summer's sun enter into decay and give its peculiar taste to the water, it would, according to my experience, be impossible to remove the taste completely by filtering through sand.

In order to obtain some direct evidence of the effect of sand filtration on the Springfield water, I advised the construction of an experimental filter on a small scale, which was done under the direction of Mr. Hancock, your Superintendent.

The filter was made by standing a cement-lined* 24-inch main on end and filling with material arranged as follows from the top downward:—

12	inches	fine sand,
12	"	coarse sand,
6	"	fine gravel,
6	"	medium gravel,
6	"	coarse gravel,
12	"	broken stone.
54	"	in all.

This material rested on a cement bottom, six inches or so in thickness. Although the work is mainly done by the very upper portion of the sand, it was thought best in the construction of the filter to imitate as far as possible the conditions which occur in filtration on the large scale. The depth of water above the sand was about $2\frac{1}{2}$ feet, and the area of filtering surface was about 3 square feet. The filter stood in a building connected

* I should here state that I am perfectly familiar from my own experience with the objections to experiments conducted on such a small scale, owing to the tendency of the water to flow along the sides of the containing vessel rather than uniformly through the material with which it is filled. This was in great measure obviated in the present case by using a *cement-lined* pipe. I may add that there was some difficulty in regulating the flow to a sufficiently small amount and at the same time causing it to be registered by the meter.

with the Water Commissioners' Office, and the water was taken from the street main by an independent pipe. The deposit in the main was occasionally disturbed by the opening of a hydrant. The water began to flow on August 1, and at the beginning was allowed to run slowly; afterwards more rapidly, as is evident from the readings of the meter which was attached.

DATE.	READING OF METER. CUBIC FEET.	AVERAGE RATE OF FLOW IN CUBIC FEET PER HOUR.
Aug. 21.	0	
Sept. 1.	52	
" 3.	375	6.7
" 4.	524	6.2
" 5.	673	6.2
" 7.	943	5.6
" 10.	1,268	4.5
" 11.	1,320	2.2
Oct. 4.	2,132	2.4

The filter began to clog so as to perceptibly affect the flow about September 25. On October 4 the flow was stopped, the water lowered in the filter, and the upper portion of sand to the depth of an inch taken for examination. The water was then allowed to flow freely through the filter until the filter became clogged; it flowed at the rate indicated by the meter-readings as follows:—

DATE.	READING OF METER. CUBIC FEET.	AVERAGE RATE OF FLOW IN CUBIC FEET PER HOUR.
Oct. 9.	2,133	
" 10.	2,228	4.0
" 19.	3,067	3.9
" 24.	3,392	2.7
Nov. 5.	3,489	

The sand taken from the filter was found to lose when ignited 0.91 per cent. of its weight; after being washed and brought into condition to be replaced it lost only 0.46 per cent., showing that it had retained a very considerable amount of organic matter. The results of the chemical examination of water taken before and after filtration, are given in the accompanying Table.

Table III.—Results of Experiments in filtering the Ludlow Water through sand.

[Results expressed in Parts in 100,000.]

No.	Date.		Unfiltered Water. Ammonia.	Unfiltered Water. "Albuminoid Ammonia."	"Albuminoid Ammonia," after filtration through paper.	Matter in Solution. Inorganic.	Matter in Solution. "Organic and Volatile."	Matter in Solution. Total at 212° Fah.
304	Aug. 30	Unfiltered,	0.0064	0.0261	0.0235	3.08	2.40	5.48
303	" 30	Filtered,	0.0061	0.0235	0.0189	4.12	2.88	7.00
312	Sept. 3	Unfiltered,	0.0139	0.0392	0.0323	4.20	2.68	6.88
313	" 3	Filtered,	0.0179	0.0275	0.0245	4.52	1.92	6.44
319	" 5	Unfiltered,	0.0083	0.0229	0.0227	2.72	2.60	5.32
320	" 5	Filtered,	0.0048	0.0248	0.0235	3.40	1.84	5.24
326	" 12	Unfiltered,	0.0087	0.0264	0.0264	3.60	2.36	5.96
327	" 12	Filtered,	0.0048	0.0219	0.0219	4.00	2.44	6.44
328	" 12	Unfiltered,	0.0088	0.0459	0.0240	3.40	3.32	6.72
329	" 12	Filtered,	0.0040	0.0216	0.0216	3.84	2.48	6.32
353	Oct. 5	Unfiltered,	0.0104	0.0520	0.0403	4.16	2.00	6.16
354	" 5	Filtered,	0.0056	0.0299	0.0299	4.36	1.52	5.88
	Unfiltered Aver age		0.0094	0.0354	0.0283	3 53	2.56	6.09
	Filtered "		0.0072	0.0249	0.0234	4.04	2.18	6.22

In collecting specimens of water for examination, the unfiltered water was first taken, and, after a sufficient time had elapsed for the water then flowing upon the filter to pass completely through, the filtered water was secured.

Before the specimens Nos. 312 and 313 were taken the water in the main had been disturbed, and the unfiltered water was quite turbid and possessed an unpleasant odor and taste, which also accompanied the filtered water. Probably a better effect would have been obtained if the water had passed more slowly, but still other experiments have convinced me of the impossibility of completely removing this taste by simple filtration through sand. Before Nos. 328 and 329 were taken the pipes were also disturbed, but the amount of sediment was then much less than before.

As a result of the experiment, it was evident that there was no difficulty in removing completely all matter in suspension, provided the flow was not too rapid. The water after filtration was generally bright and clear. There was a trifling increase in the amount of inorganic matter, due no doubt to the action of the water on the material of the filter. It was further evident that there was a slight decrease in the organic matter which was in a state of solution in the water, as may be seen by comparing the amounts of "albuminoid ammonia" obtained from the respective waters after filtration through paper. This "albuminoid ammonia" may be taken as an index of the relative amounts of nitrogenous matter. It was further evident a sand filter could not be relied upon to remove completely all unpleasant tastes which might at times affect the water of the reservoir.

In conclusion I may say that, as there is no proof that the water is unwholesome during the few weeks when it is liable to be somewhat unpleasant to the taste, and as the annoyance seems to be less each succeeding year, I do not feel justified in recommending at the present time any scheme for filtration. If, however, it should ever be thought desirable or necessary, it is only a question of expense. There is no doubt of the practicability of filtering the water so as to improve it appreciably.

I have been asked to express an opinion of the comparative wholesomeness of the Ludlow water and the waters of the wells in the city. My knowledge of the well-waters is derived from the "Report of the Chemist" in the Report of the Board of Water Commissioners for 1875. The following Table contains some of the results of the examinations there recorded. Taking these figures in connection with the observations recorded by the person making the examinations, I should not hesitate to prefer the Ludlow water to the waters of the wells. The mere presence of a greater amount of dissolved substances would not in itself be a reason for pronouncing the wells unsuited for use, but they all with one exception showed evidence of pollution. For washing and cooking, the water of the wells is objectionable on account of its *hardness*. The Ludlow water is practically unpolluted, and the water is very soft.

Yours very respectfully,

WM. RIPLEY NICHOLS.

MASS. INSTITUTE OF TECHNOLOGY, Boston, Jan. 1, 1878.

Table IV — Examination of Water from Springfield, Mass.

[Results expressed in Parts in 100,000.]

No.	Date.	Locality.	Solid Residue. Inorganic.	"Organic and Volatile."	Total at 212° Fah.	Authority.
6*	October 6, 1871	Bateman's Well, Union Street,	25.4	5.3	30.7	S. Dana Hayes.
7*	"	Well, cor of Union and Mulberry Streets,	13.4	3.5	16.9	"
8*	"	Well, Rockingham House, State Street,	16.1	4.6	20.7	"
9*	"	Pipe Well, No. 74 Congress Street,	15.1	3.5	18.6	"
10*	"	Bradley's Well, No. 58 Pynchon Street,	19.8	3.3	23.1	"
	July–Dec , '76	Ludlow Water. Average of 45 Samples,	2.09	2.86	4.95	W. R. Nichols.
	Jan.–Sept., '77	" " Average of 33 Samples,	2.09	2.69	4.76	"

* These results were stated in grains to the U. S. gallon, but have been calculated into Parts per 100,000, in order to afford means of comparison with the Ludlow water.